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# ACQUISITION OF PHYSIOLOGICAL DATA DURING G-INDUCED LOSS OF CONSCIOUSNESS (G-LOC)

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The voluntary, fully informed consent of the subjects used in this research was obtained as required by AFR 169-3.

The animals involved in this study were procured, maintained, and used in accordance with the Animal Welfare Act and the "Guide for the Care and Use of Laboratory Animals" prepared by the Institute of Laboratory Animal Resources - National Research Council.

The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

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The objective of this study was to develop a data acquisition system for the small animal centrifuge (SAC) and the transcranial Doppler (TCD) and to perform required research into the hemodynamic/biochemical alterations during G-induced loss of consciousness (G-LOC). This effort was to include the daily operation and maintenance of the SAC and Waters High Performance Liquid Chromatography units. The original data were turned over to the Flight Motion Effects Branch. The results of this effort were published as the article and abstracts included in this technical paper.

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PART A

# TRANSCRANIAL DOPPLER STABILIZATION DURING ACCELERATION AND MAXIMAL EXERCISE TESTS

Jemett L. Desmond, B.S. and Paul M. Werchan, Ph.D.

Published in the 29th Annual SAFE Symposium Proceedings. 1991:272-3.

**ABSTRACT.** The transcranial doppler (TCD) is used as a non-invasive technique to measure cerebral blood flow (CBF) velocity. It has been applied to the clinical and diagnostic settings, although the measurement could be useful in aerospace physiology research as well. Initial use of TCD during acceleration stress and maximal-effort cycling exercise revealed that the commercially available probe assembly did not provide: 1) adequate stabilization of the TCD probe to prevent movement during centrifugation and maximal exercise, 2) ease of focusing on middle cerebral artery (MCA) and, 3) secure locking mechanism to prevent probe dislocation during head movement. Because of the above difficulties, a functional TCD probe, probe support, and headgear assembly was designed and fabricated. The criteria consisted of the following: 1) subject comfort, 2) focusing ability, 3) signal maintenance and 4) compatibility with other monitoring devices used during acceleration and exercise related research. This paper will discuss fabrication, instrumentation techniques, and stabilization methods for transcranial doppler use in aerospace physiologic research at the Armstrong Laboratory, Brooks AFB, TX.

**INTRODUCTION.** The transcranial Doppler (TCD) is used as a noninvasive technique to measure cerebral blood flow (CBF) velocity. The TCD has been applied to the clinical and diagnostic settings and most recently in aerospace physiology research. For many years, measurements with conventional Doppler devices operating in the range from 5-10 MHz were not obtainable during noninvasive intracranial studies due to poor penetration of ultrasound through the skull. Bone attenuates the ultrasonic wave, making it almost impossible to record noninvasively the blood velocity of intracranial arteries (1). In 1982 Rune Aaslid using a 2-MHz pulsed Doppler technique was able, for the first time, to record the velocity of blood in the intracranial arteries, through an "ultrasonic window" (2). Three ultrasonic windows are possible in the temporal region above the zygomatic arch. These windows include the anterior window (AW), middle window (MW), and posterior window (PW). Usually, only one or two windows can be located through which maximum amplitude of the Doppler signals can be obtained. Thus, the position and angle of the TCD probe are critical in monitoring Doppler signals. The vessels of interest are very small, only 1-2 mm in diameter, a movement of just 1 mm can be the difference in finding and keeping a good Doppler signal.

A recent study, conducted at the Armstrong Laboratory, Brooks AFB, required the monitoring of CBF during both acceleration testing (up to 7 $+G_z$ for sustained periods of time) and maximal cycling exercise testing. This study also used a Hewlett Packard ear oximeter, a MBU-20/P oxygen mask, and an oxygen mask head strap assembly. A TCD probe assembly, compatible with both the ear oximeter and oxygen mask head gear, was needed for this study. This paper will discuss the fabrication, instrumentation techniques, and stabilization methods of the TCD probe implemented in this study.

**METHODS.** A cap was made to support the ear oximeter probe and its fiber optic cord. The cap was made of Nomex with lacing sewn down the middle of the cap to provide adjustment for varying head sizes and shapes. Rubber reinforcements were sewn around ear space to support ear oximeter probe and fiber optic cord. A row of five snaps was sewn on each side of the cap at cheek level for attachment and adjustment of oxygen mask. To prevent slippage of the oxygen mask down the subjects' nose during acceleration and exercise, a strap was sewn to the bridge of the mask and attached with a buckle to the top of the oxygen head strap assembly. An area of 5 cm (2 in.) by 5 cm (2 in.) was removed from left temple region of cap to access the 'ultrasonic window."

Initial use of TCD during acceleration and exercise revealed that the TCD assembly used did not provide: (1) adequate stabilization of the TCD probe to prevent movement during centrifugation and maximal exercise, (2) ease of focusing on middle cerebral artery (MCA), and (3) a secure locking mechanism to prevent dislocation during head movement. Because of these difficulties, a functional TCD probe, probe support, and headgear assembly were designed and fabricated. The device criteria consisted of the following: (1) subject comfort, (2) focusing ability, (3) signal maintenance, and (4) compatibility with other monitoring devices used in aerospace physiology research.

The first TCD probe assembly incorporated a TCD probe and monitoring unit from the Institute of Applied Physiology and a welders' headband padded and lined with sheepskin. Gross movement and focusing of this probe was accomplished using a T bracket angled at 15 degrees towards the head, and attached to the headband with a wing nut and screw. Fine adjustment of the probe was achieved by using a ball and socket joint that locked the probe in place using a tightening screw.

The second probe assembly and headband used incorporated a Medisonics Dual TCD headband and probe. The headband was cushioned with foam that attached and detached with Velcro. The probe assembly again used a T bracket for gross movement and focusing; but the T bracket was not angled. Fine adjustment of the TCD probe was accomplished with a ball and socket joint. An elbow joint and extending rod attached to the socket of the ball and socket joint was used to lock the probe in place.

The third, and most successful TCD assembly and headband used in the study again used the Medisonics Dual probe headband, but also incorporated an Eden Medical Electronics (EME) TCD probe assembly and monitoring unit. This probe assembly used an I bracket with no angle. For gross movement and focusing the TCD probe attached to the headband with a nut and screw. Fine adjustment of the TCD probe was again accomplished using a ball and socket joint. This TCD probe had a removable handle to assist in focusing. The probe locked in place with a flip switch locking mechanism.

**RESULTS.** The first TCD probe assembly and headgear using the sheepskin lined welders headband caused hot spots on some subjects. The 15% angle of the T bracket seemed to cause subject discomfort in the temporal region, plus did not allow enough range of motion for focusing the TCD probe through the ultrasonic window onto the MCA.

The second TCD probe assembly and head gear improved the comfort of subjects. The foam prevented hot spots from occurring on the subject's forehead and proved to be stable. The T bracket was not anlged toward the head as the first T bracket, thus relieving the pressure at the temple region from the TCD probe, but did not provide enough flexibility for focusing the probe on the MCA. The elbow joint locking system of the TCD probe was easy to use and the probe remained secure in the socket during acceleration and exercise stress. However, some loss of Doppler signal still occurred, due to vessel or probe assembly movement.

The third TCD assembly and headband provided more comfort and stability than the two previous assemblies. The I bracket seemed to provide more flexibility in gross movement and focusing of the TCD probe than the T bracket. The removable handle of the TCD probe made focusing easier, and integrated better with the cap, ear oximeter, oxygen mask, and oxygen mask head strap.

Unfortunately, the locking mechanism of the (EME) TCD probe was not as secure as the Medisonics TCD probe, using the elbow joint. Thus, some probe movement still occurred during data collection.

**CONCLUSION.** The third TCD probe assembly provided the easiest and most reliable system for monitoring the MCA during acceleration and maximal exercise. The assembly worked well with cap, ear oximeter, and mask. Subjects reported the assembly to be comfortable throughout the experiments, the only problem with the third assembly seemed to be with the locking mechanism of the probe. An elbow joint might provide the easiest and best way to secure the TCD probe.

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PART B

# RAT BRAIN EDEMA AFTER MULTIPLE +Gz EXPOSURES

Judy A. Barber, B.S., Asha R. Shahed, Ph.D., and Paul M. Werchan, Ph.D.

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Aviation Space and Environmental Medicine. 1992. 63:425.

**INTRODUCTION.** Phenomena of acceleration or +Gz induced loss of consciousness (G-LOC) is known to occur in pilots of high performance aircraft and has been reproduced in animal models in the laboratory. It has been demonstrated that during +Gz exposure cerebral blood flow is significantly reduced resulting in brain ischemia. This situation could be repeated several times by pilots during flight maneuvers. Unfortunately, we know little about pathological effects on the brain. One of the earliest pathologic changes of ischemic stress is brain edema. In the present study occurrence of brain edema in the rat after +Gz exposure was investigated. **METHODS.** Male rats (n=4) were exposed to 6, +25 Gz runs with 5 min rest period between each run. Brains were removed 15 min, 30 min, 3 hr, and 24 hrs (n=5 in each group), after the last centrifuge run, and weighed (wet weight) and then oven dried to constant dry weight. The ratio of wet to dry weight was used to assess % change in brain's water content (edema). **RESULTS.** The data show that % of water in brain tissue increased significantly up to 3 hr after the centrifuge run, but not after 24 hr. The largest increase in water (2%) was observed at 15 min. **CONCLUSION.** These results show that multiple +Gz exposure can cause brain edema. Edema can result in post +Gz exposures hypoperfusion and could cause secondary ischemia thus exacerbating the functional effects related to G-LOC.

PART C

# ESTIMATION OF CEREBRAL BLOOD FLOW VOLUME IN RATS DURING +Gz STRESS

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Aviation Space Environmental Medicine. 1992. 63:424.

**INTRODUCTION.** +Gz induced loss of consciousness (G-LOC) has been proposed to result from a critical reduction of cerebral blood flow (CBF) during high +Gz stress. However, an accurate measurement of CBF during +Gz has been difficult to accomplish. Methods such as transcranial Doppler and radiolabelled microspheres have been used in humans and primates to measure CBF, but neither method estimates residual blood in the brain during +Gz stress. In the present study, 3 other methods to estimate CBF in rats and mice were used. **METHODS.** Rats were exposed to a single +25 Gz and brain samples were collected by freeze fixation at desired times. Mice, similarly were exposed to +15 to 35 Gz for 30 s and brains were fixed by microwave. Brain tissue hemogenates were analyzed for total protein, hemoglobin (Hb) and iron (Fe). **RESULTS.** Total protein (25%) and Hb (38%) content decreased maximally 15 s after onset of +25 Gz in rats. Total FE content showed a similar decrease. Total protein concentration in mice brain decreased at +20 Gz and higher. Hb and Fe content in mice brain tissue are being investigated. **CONCLUSION.** The decreases in total protein and Hb are indicators of a decrease in total blood flow to the brain. But the presence of Hb suggests that trapped blood remains in the brain. We believe that this residual blood acts as an energy pool that could delay the onset of G-LOC in a high +Gz environment that follows a decrease in carotid artery blood pressure.

PART D

# USE OF EEG SPECTRAL ANALYSIS TO IDENTIFY G-INDUCED LOSS OF CONSCIOUSNESS (G-LOC) IN THE RAT

Sharon K. Garcia, B.S., John R. Garza, B.A., Douglas J. Coffey, B.S., and Paul M. Werchan, Ph.D.

Published as an abstract in
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**INTRODUCTION.** Despite numerous technological advances to improve G-tolerance, loss of consciousness due to +Gz stress continues to be a problem with fighter pilots. In recent years, research has focused on the use of EEG relating G-LOC with cerebral activity. It has been shown that with G-LOC EEG amplitude decreases and can become isoelectric. However, the isoelectric point may occur beyond useful consciousness. Thus changes in EEG frequency components during this period may be a more sensitive indicator of the level of consciousness. **METHODS.** Male rats (250-350g), with surgically implanted bipolar parietal electrodes, were exposed to +25 Gz in a small animal centrifuge until loss of EEG amplitude (G-LOC). EEG recordings were obtained for each rat and subjected to EEG spectral analysis. **RESULTS.** Preliminary results suggest that during baseline and onset of acceleration EEG activity consisted of all component frequencies from 0-30 Hz. Early in the G exposure there was a significant shift towards the delta frequency band (0-4 Hz). At the point of isoelectric EEG, delta frequency disappeared along with other frequencies. Early recovery following G exposure was again marked by a pronounced increase in delta activity. **CONCLUSION.** Spectral analysis of EEG provides a more objective/sensitive approach to G-LOC detection by identifying changes in component frequencies.